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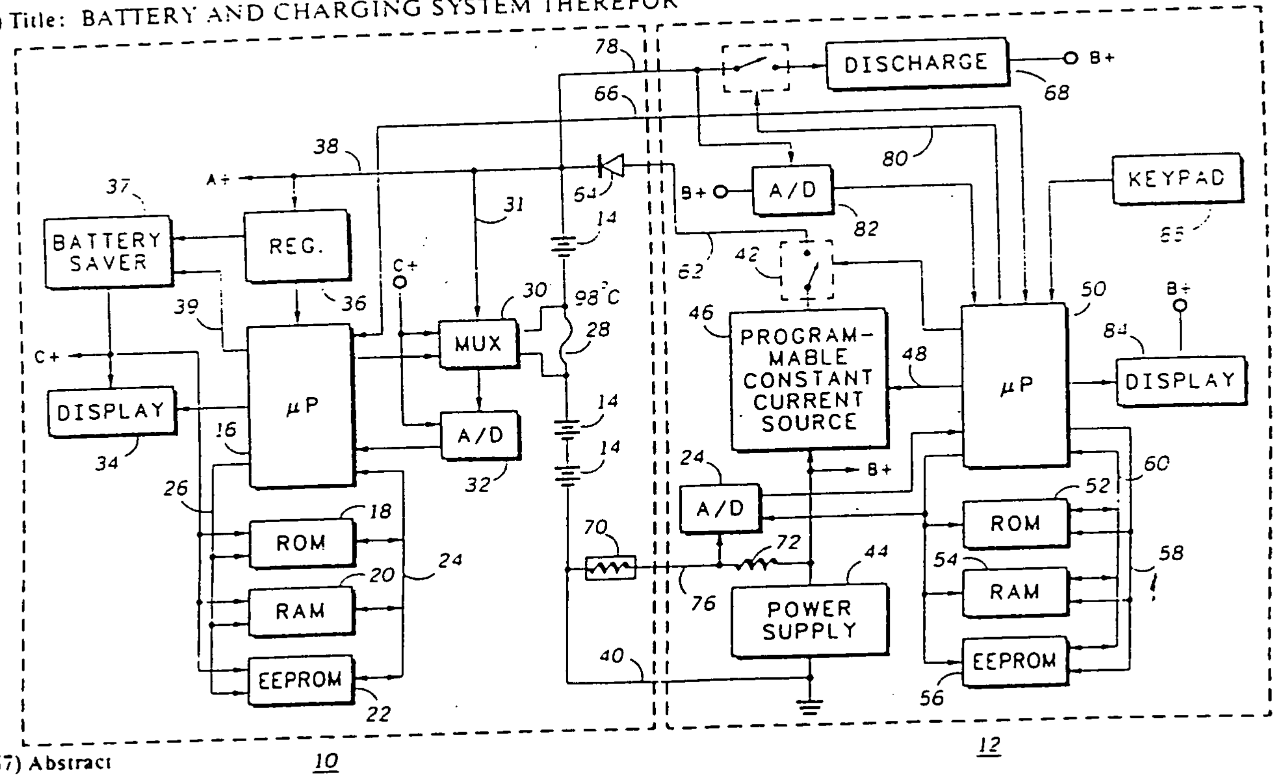
(54) Title: BATTERY AND CHARGING SYSTEM THEREFOR



(57) Abstract

Batteries (10) are constructed and arranged to retain a historical record of their use (discharge), capacity, and discharge/recharge cycles. This historical battery use data may be retrieved and analyzed by a charging system (12) to optimally recharge the battery (10) thereby maximizing battery life, while avoiding the "memory effect" problems of the prior art.

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BATTERY AND CHARGING SYSTEM THEREFOR

Technical Field

This invention relates generally to rechargeable batteries and battery chargers, and more specifically to a cooperative rechargeable battery system for facilitating battery recharging, while optimizing useful battery life.

Background Art

Portable devices routinely depend upon batteries as a power source. To ease battery replacement costs, rechargeable batteries have found wide utility in powering contemporary consumer and business products. For example, nickel cadmium batteries may be repeatedly used to energize computers, radios, pagers and other such devices. As is known, rechargeable batteries may be readily re-energized after use (discharge) via a recharging unit.

A particular problem with rechargeable batteries, however, arises when the battery (or the cells therein) are repeatedly subject to a full recharge after only a partial or incomplete discharge. For example, if a product powered by a rechargeable battery were used only a portion of each day, and the batteries were allowed to fully recharge each evening, the batteries may, over time, develop a voltage depression phenomena (commonly

referred to as the "memory effect"), which may reduce the battery's useful capacity.

To avoid the "memory effect", some designers of battery charging systems prefer to fully discharge a battery prior to each recharging cycle. However, this technique reduces the useful life of the battery since a rechargeable battery may only be fully discharged and recharged a limited number of times. Thus, by unnecessarily discharging a battery prior to recharging, reduced battery life may be balanced against avoidance of the "memory effect" problem. Accordingly, a need exists in the art to provide a method for avoiding the "memory effect" problem, while optimizing useful battery life.

Summary of the Invention

Accordingly, it is an object of the present invention to provide a battery and charging system that avoids the detriments of the prior art.

Briefly, according to the invention, batteries are constructed and arranged to retain a historical record of their use (discharge), capacity, and discharge/recharge cycles. This historical battery use data may be retrieved and analyzed by a charging system to optimally recharge the battery thereby maximizing battery life, while avoiding the "memory effect" problems of the prior art. Additionally, the historical battery data may be accessed by a device being powered by the battery so as to provide the device operator with information regarding the battery's capacity, useful life, and inform the operator when recharging is required.

Brief Description of the Drawings

Figure 1 is a block diagram illustrating a preferred embodiment of a battery and charging system in accordance with the invention;

Figure 2 is is a block diagram illustrating another preferred embodiment of a battery and charging system in accordance with the invention.

Detailed Description of the Preferred Embodiment

Referring now to Figure 1, there is shown a battery (10) and a charging unit (12) in accordance with the present invention. The battery (10) is comprised chiefly of several cells (14), which collectively form an energy storage means. Additionally, the battery (10) includes a controller (or use monitor) comprising a microprocessor (16), which communicates via an address bus (26) and a data bus (24) with a suitable amount of read-only memory (ROM) (18), random access memory (RAM) (20), and electronically eraseable programmable read-only memory (EEPROM) (22). Preferably, the microprocessor's operational instructions (program) reside in the ROM, while semi-permanent and temporary information may be stored in the EEPROM and RAM respectively.

Typically, one or more temperature activated fuses (28) are employed in conventional batteries to provide protection in the event that the internal temperature of the battery should rise above a predetermined level. According to the present invention, one of these fuses may be used to measure the rate of current discharged from the battery by measuring the voltage drop across the internal resistance of the fuse. Thus, the battery (10) is preferably provided with a multiplexer (30), which routes the voltage present on each side of the fuse (28) to the microprocessor (16) via an analog to digital (A/D) converter (32). Further, the multiplexer (30) is coupled (31) so as to enable the microprocessor (16) to determine the present battery voltage. In this way, the battery (10) may determine its discharge rate, and, while in use, may provide a user with information regarding the

battery's capacity, useful life, and inform the user when a recharge is required via a display (34).

Each of the above described components are powered by the battery itself using either a regulated (36) or unregulated (38) version of the battery's energy. Preferably, each of the battery's active components are constructed using complementary metal oxide semiconductor (CMOS) technology, or comprise other suitable low current drain devices. According to the invention, the battery (10) is provided with a battery saver (37), which may be activated (39) by the microprocessor (16) so as to conserve energy. Preferably, the battery (10) of the present invention activates the battery saver (37) after completing communication with the charging unit (12). Further, when powering a battery powered device, the battery saver (37) may be activated either independently or in response to an operational status of the battery powered device. That is, should the battery powered device enter a low current mode (i.e., standby), or be switched off, the battery saver (37) would be activated in response thereto so as not to be consuming battery power. Conversely, should the battery (10) be in the battery saving mode at a time when the battery powered device enters a higher power consuming state (i.e., transmitting), the battery (10) leave the battery saving mode to monitor the battery powered device. In this way, battery use (discharge) history data may be generated and maintained without unduly consuming energy.

Referring still to Figure 1, the charging unit (12) may be seen to be controlled by a microprocessor (50), which communicates via an address bus (58) and a data bus (60) with a suitable amount of ROM (52), RAM (54) and EEPROM (56). Additionally, the major elements of the charging unit (12) include a programmable constant current source (46), which may be programmed (48) by the microprocessor (50) to provide at least a rapid charging current and a trickle charging current, and a

discharge circuit (68), which is constructed and arranged to reduce any energy remaining in the battery (10) to a sufficient level to avoid any "memory effect" problems after recharging.

As can be seen, the charging unit (12) interacts with the battery (10) at five contact points. Initially, a common ground or return (40) is established. Also, the charging current is presented to the battery at a second contact (62). As is known, within the battery (10) a diode (64) is employed to prohibit unwanted discharge of the battery. A separate discharge path is provided at a third contact (66) when a discharging current flow is required. The remaining two contact points provide information which may be used to facilitate the charging of the battery. To determine the charging time, it is known to employ a thermistor (70), which may be biased by a resistor (72) in the charging unit (12). The voltage at a sensing contact (76) may be digitized (74) to enable the microprocessor to determine the internal temperature of the battery. Further, by taking two or more such measurements over known time intervals, the rate of the battery's temperature rise (charging rate) may be determined. Moreover, other information regarding the battery's charging requirements may be provided to the charging unit (12) via a serial communication link (78) (which couples the microprocessor (16) of the battery (10) with the microprocessor (50) of the charging unit (12)). In this way, data representing the battery's identification code, model (or battery type) code, past charging history, and past use (discharge rate) history may be provided to the charging unit (12). Of course, after the battery has been recharged, the battery may communicate with a device, such as a two-way radio, via the serial communication link (78).

Operationally, the charging unit (12) is designed to selectively (42) present a sufficient charging current to the battery (10) so as to replenish any dissipated energy. According to the invention, this is accomplished by first requesting data from the

battery. Preferably, the data received from the battery (10) includes at least a battery identification code, use (discharge rate) information, and data indicating the number of recharge cycles since the last discharge of the battery (either through use or discharges prior to recharging). If the number of charging cycles since the last discharge equals or exceeds a threshold, the battery (10) is discharged prior to charging by coupling (80) the battery to the discharging circuit (68). Otherwise, the charging unit (12) determines the optimum charging time by analysis of the use (discharge rate) data either separately or in conjunction with digital representations (82) of the battery's total voltage, and/or measurement of the battery's internal temperature (via the sensing contract (76)). All or a portion of this information may be accessed by and/or presented to an operator via a display (84) either automatically, or under the command or inquiry of the operator which may be entered via a keypad (85).

By use of the historical battery charging and use (discharge rate) data in conjunction with information regarding total battery voltage and internal battery temperature, the microprocessor (50) may program (48) the programmable constant current source (46) to achieve a rapid charging cycle (i.e., minimized charging time) that will not unduly overheat or overcharge the battery. Thus, the useful life of the battery is maximized. Also, by discharging the battery only after a predetermined number of charge cycles relative to the last discharge, the "memory effect" may be avoided while battery life is optimized. Lastly, by tracking the total number of discharge/recharge cycles in the battery memory (22), the charging unit (12) and/or the battery (10) may inform (via displays (34) and (84) respectively) a user when the battery has reached (or is about to reach) the end of its useful life.

At the conclusion of the charging cycle, the charging unit (12) may send updated charging information to the battery (10)

via the serial communication link (78) to be processed (16), stored (22), and optionally displayed (34) by the battery. Such information may include, but is not limited to, incrementing the history of total discharges; incrementing the number of charges relative to the last discharge; the total charging time; and, the total battery voltage after charging. All or a portion of this information may be accessed by and/or displayed to a user during use of the battery. Of course, in accordance with the invention, this information may again be retrieved, processed, updated, and stored during the next charging cycle.

Referring now to Figure 2, an alternate arrangement of a battery (10') and charging unit (12) is shown. As can be seen, the battery (10') of Figure 2 includes a microcontroller (130), which preferably comprises an MC68HC11 microcontroller manufactured by Motorola, Inc., or its functional equivalent. In this embodiment, the microcontroller (130) communicates via a serial link (78') with a microprocessor (100), which is controlling a two-way radio (102) that the battery (10') is powering. The microprocessor (100) of the two-way radio (102) also communicates via an address bus (104) and a data bus (106) with a suitable amount of ROM (108), RAM (110), and EEPROM (112). Additionally, the major elements of the two-way radio (102) include a transmitter (114) and a receiver (116), which may be selectively (118) coupled to an antenna (122) via an antenna switch (120). Optionally, the two-way radio (102) may include a display (124) and a keypad (126). Preferably, all major elements of the two-way radio (102) are powered by a regulated (128) version of the battery's energy received at a contact (66'). To conserve power, it is known to employ a battery saver (127), which may be activated (129) by the microprocessor (100) to enter a low power mode. According to the invention, the activation, deactivation, or other operational mode variations of the radio (102) may be communicated to the battery (10') via the

serial link (78'). This information may be used by the battery (10') to more efficiently monitor the radio's use of energy.

The microcontroller (130) of the battery (10') is powered by a regulated (132) version of the battery voltage, and includes a memory (130") for storing both charging history and use (discharge rate) data. By accessing this data, the radio (102) may provide information to an operator via the radio's display (124). Also, information calculated by the microprocessor (100) of the radio (102) may be stored within the battery by sending it to the microcontroller (130). Additionally, the microcontroller (130) includes several conversion ports (130'), which receive each side of a protective fuse (28), which is typically included in batteries to protect the cells (14). Also, the microcontroller (130) coupled to the diode (64), which, in this embodiment, enables the microcontroller to determine the present battery voltage. By using this information, the microcontroller (130) may determine the use (discharge) rate of the battery (10'), and may display information regarding remaining operational time to the operator.

To conserve power, the battery (10') may enter the battery saving mode after determining that the discharge rate of the battery has met or fallen below a given threshold. Alternately, the radio (102) may inform (78') the battery (10') that the radio has been switched off or entered a low power mode (i.e., standby). In this way the battery (10') may enter the battery saving mode either independently or in response to an operational status change of the radio. Conversely, should the battery (10') be in the battery saving mode at a time when the radio (102) enters a higher power consuming state (i.e., transmitting or receiving), the battery (10') may leave the battery saving mode to monitor the battery powered device after receiving a status change message from the radio. In this way, battery use (discharge) history data may be generated and maintained without unduly consuming energy.

Preferably, this information may be used later by the charging unit (12) to facilitate charging in accordance with the invention.

After use is complete, or after informing the two-way radio operator of limited remaining battery energy, the battery (10') is coupled to the charging unit (12) to replenish the battery's energy. Preferably, the microcontroller (130) of the battery (10') also enters the battery saving mode after completing communication with the charging unit (12). During charging, the two-way radio (102) may remain coupled to the battery (10') or may be removed so as to remain in service by using another battery. The charger (12) operates as discussed above in conjunction with Figure 1, except that the microprocessor (50) of the charging unit (12) must retrieve (and/or store) information from the microcontroller (130) of the battery (10') via the serial link (78) as discussed above. In this way, the cost, size, and weight of the battery (10') is reduced by employing a single microcontroller to control data gathering, storage, retrieval, and processing.

What is claimed is:

Claims

1. A method for charging a battery, comprising the steps of:

(a) receiving data from the battery;

(b) processing at least a portion of said data to determine at least whether the battery should be discharged prior to charging;

(c) discharging the battery when step (b) determines that the battery should be discharged prior to charging;

(d) charging the battery.

2. The method of claim 1, wherein said discharging step comprises the step of reducing energy stored in the battery to a predetermined threshold.

3. The method of claim 1, wherein said processing and determining step comprises:

(b1) processing at least a portion of said data to determine a value representing when the battery was last discharged prior to charging;

(b2) determining to discharge the battery prior to charging when said value at least exceeds a threshold.

4. A battery, comprising:

energy storage means for storing energy; and,

means for storing data representing at least charging information.

5. The battery of claim 4, which includes means for monitoring said energy storage means and for generating said data representing at least charging information.

6. The battery of claim 5, which includes display means, coupled to said monitoring means, for displaying at least a portion of said data representing at least charging information.

7. A battery, comprising:

energy storage means for supplying energy;

means for coupling the battery to a device;

means for monitoring said energy storage means, and for communicating with said device;

means responsive to said monitoring means for temporarily reducing dissipation of said energy storage means.

8. A battery charging apparatus, comprising:

means for receiving data from the battery;

processing means for processing at least a portion of said data, and for determining whether the battery should be discharged prior to charging;

means for discharging the battery when said processing means determines that the battery should be discharged prior to charging; and,

means for charging the battery.

9. In a communication system having at least one battery powered communication device, a method for charging a battery, comprising the steps of:

at said at least one battery powered communication device:

(a) generating data representing at least charging information;

(b) transmitting at least said data representing at least charging information to the battery;

at the battery:

(a) receiving at least said data representing at least charging information from said at least one battery powered communication device;

at said battery charging unit:

(a) retrieving said data representing at least charging information from the battery;

(b) processing at least a portion of said data representing at least charging information and determining whether the battery should be discharged prior to charging;

(c) discharging the battery when step (b) of said battery charging unit determines that the battery should be discharged prior to charging; and,

(d) charging the battery.

10. In a radio frequency communication system having at least one battery powered communication device capable of communicating information via a radio frequency communication channel, a battery charging system comprising:

a battery powered communication device comprising:

means for transmitting information over at least one radio frequency communication channel;

means for receiving information over said at least one communication channel;

means for generating data representing at least charging information;

a battery comprising:

energy storage means for storing energy suitable for powering said battery powered communication device;

means for storing said data representing at least charging information;

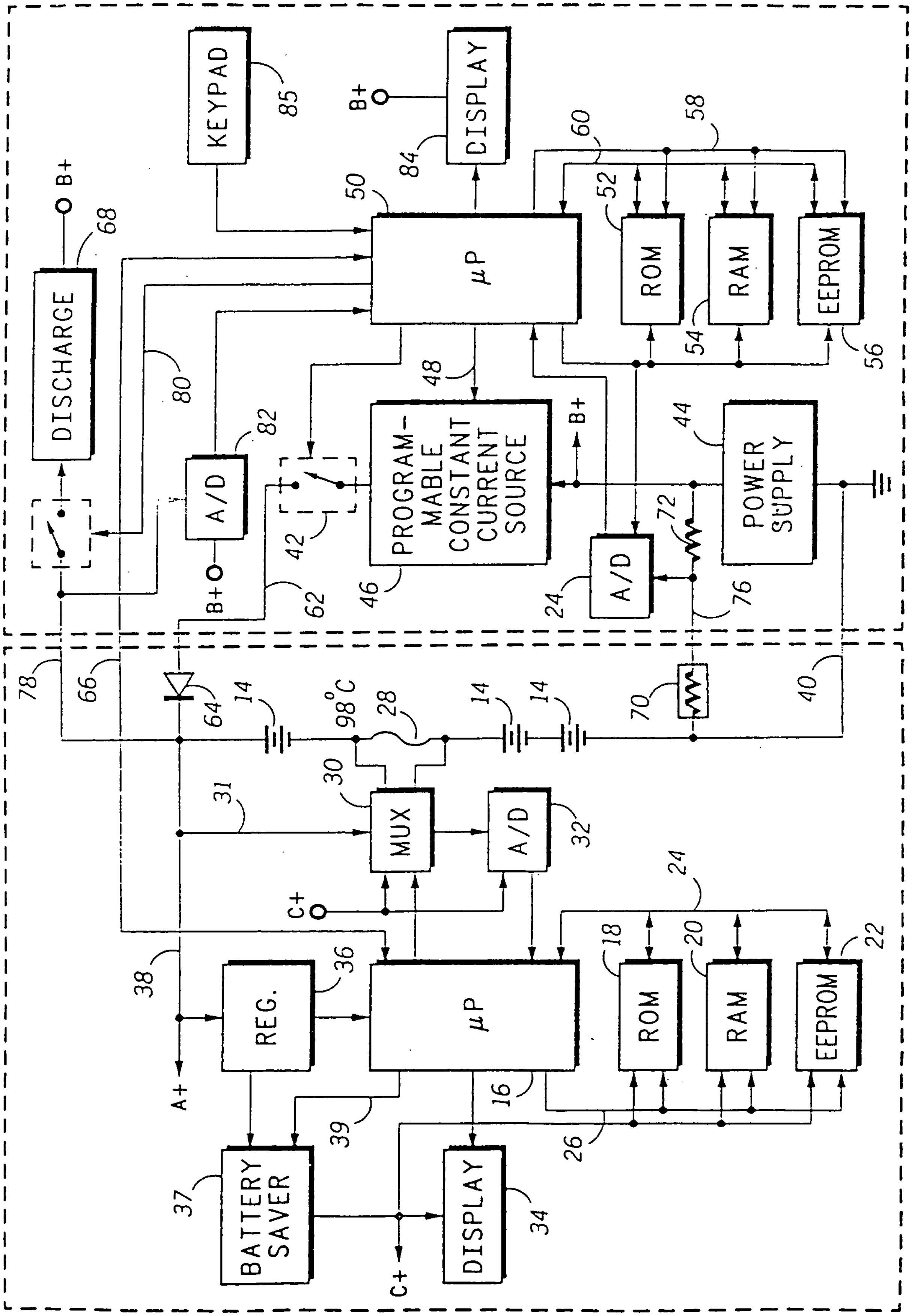
a battery charging unit comprising:

means for retrieving said data representing at least charging information;

processing means for processing at least a portion of said data representing charging information, and for determining whether said battery should be discharged prior to charging;

means for discharging said battery when said processing means determines said battery should be discharged prior to charging; and,

means for charging said battery.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CONSTANT
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SOURCE
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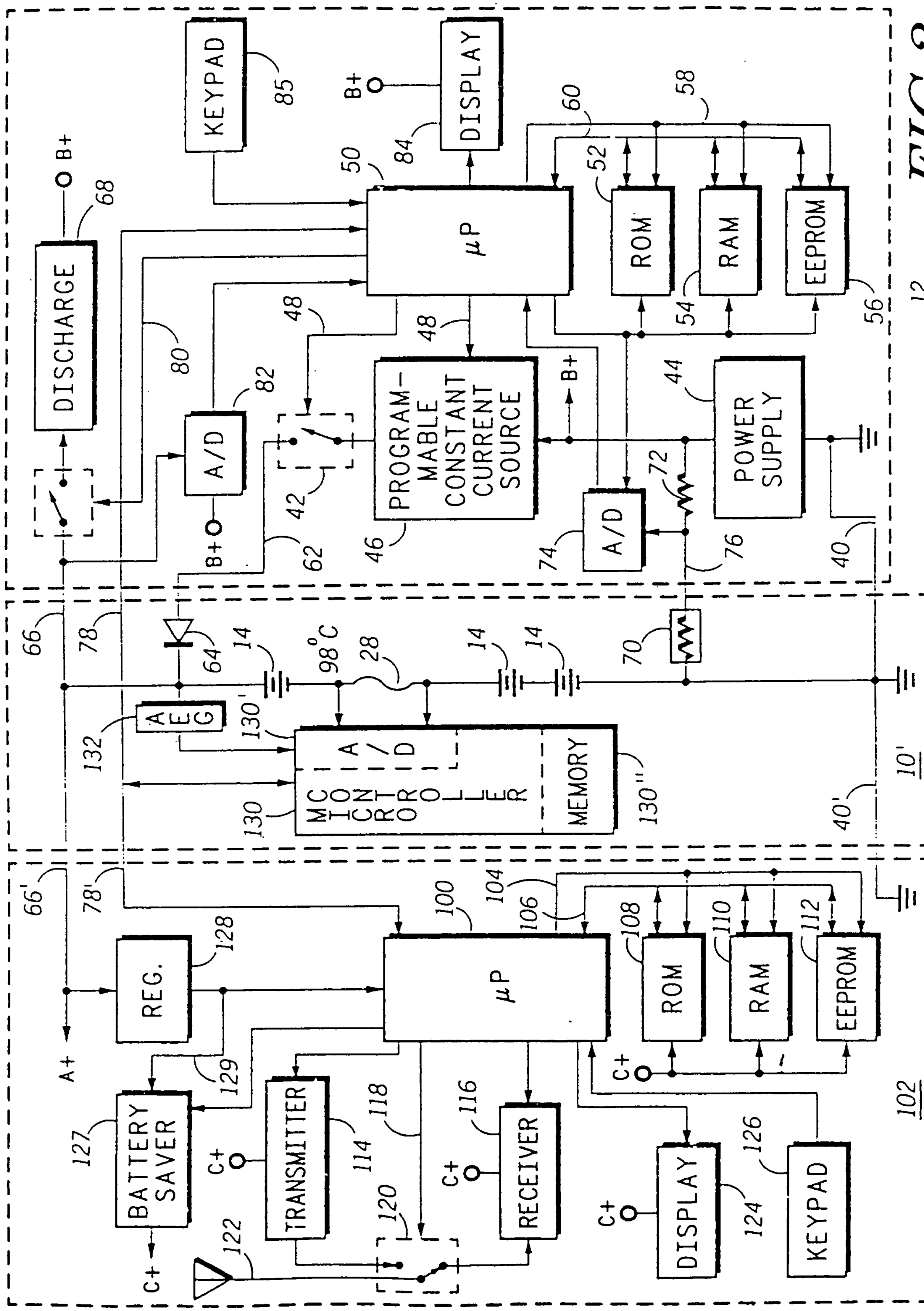
REG.
A+
BATTERY
SAVER
10
12

FIG.1

2/2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DISPLAY
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PROGRAM-MABLE CONSTANT CURRENT SOURCE
POWER SUPPLY
MICROCONTROLLER
A/D
MEMORY
98°C
REG.
BATTERY SAVER
TRANSMITTER
RECEIVER
A+
B+
C+

FIG.2

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/03462

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (4): H02J 7/00
U.S. Cl.: 320/14

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	320/13,14,20,21,39,40,44,48

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US, A, 4,709,202 (KOENCK ET AL) 24 November 1987, See Figs. 3 and 4; col. 4, lines 66-68; col. 1, lines 50-60; col. 5, lines 1,2,54,55; col. 2, lines 3-15; col. 7, lines 57-59; col. 11, lines 68 to col. 12, line 1; col. 18, lines 5-11; col. 54, lines 30-34.	1-10 4716354 H02J7/00
X	US, A, 4,749,934 (ALEXANDER ET AL) 07 June 1988, See Fig. 1, element 40.	7
A	US, A, 4,639,655 (WESTHAVER) 27 January 1987, See abstract.	1-10

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
15 September 1989	16 JAN 1990
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Robert J. Hickey Robert J. Hickey

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